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A HUMAN FACTORS EVALUATION OF THE ALBEDOS HUMAN-MACHINE INTERFACE FOR SEARCH AND RESCUE

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ABSTRACT

ALBEDOS (Airborne Laser Based Enhanced Detection and Observation System) is an active imaging device designed to enhance surveillance capability at night and under degraded weather conditions. It is currently being developed for use in search and rescue (SAR) operations. DCIEM was requested to carry out a human factors evaluation of the ALBEDOS human-machine interface (HMI) as part of a technical evaluation of the system. The human factors evaluation included a desktop analysis of the HMI for compliance with MIL-STD-1472D and structured interviews with potential users of the system. The users participated in the technical trials and carried out several scenarios that involved detecting and identifying targets at night.

The results of the desktop evaluation indicated that the current ALBEDOS interface does not meet MIL-STD-1472D. The participants' comments supported this finding. They thought that the system could be useful for identifying targets at night and under degraded weather conditions. However, due to the current physical and manpower constraints of the SAR environment, the interface should be simplified considerably and many of the functions should be automated.

Alternative concepts for the ALBEDOS HMI are discussed. It is recommended that these concepts be prototyped and evaluated by potential users. In some cases, functions were not tested sufficiently because of time constraints and the inexperience of the participants. Thus, clear recommendations could not be made. In those cases, suggestions for further evaluations are presented. In addition, feasibility studies on automating certain functions are proposed.

EXECUTIVE SUMMARY

ALBEDOS (Airborne Laser Based Enhanced Detection and Observation System) is an active imaging device designed to enhance surveillance capability at night and under degraded weather conditions. It was developed by WestCam Inc. under contract to the Defence Research Establishment Valcartier (DREV). The system is currently being developed for use in search and rescue (SAR) operations. However, it could be useful in a wide range of surveillance roles.

The Defence and Civil Institute of Environmental Medicine (DCIEM) was requested to carry out a human factors evaluation of the ALBEDOS human-machine interface (HMI) as part of a technical evaluation. The human factors evaluation included a desktop analysis of the HMI for compliance with MIL-STD-1472D and structured interviews with SAR experts who participated in the technical trials. The SAR experts carried out several scenarios with the system during the in-flight trials that involved detecting and identifying targets at night. During the interviews, the participants were queried on the potential use of the system in SAR operations, the functionality they would like such a system to have, their impressions of and suggestions for the HMI, and what functions they would like to see automated.

The results of the desktop evaluation indicated that the current interface does not meet MIL-STD-1472D. The participants' comments supported this finding. They thought that the system could be useful for identifying targets at night and under degraded weather conditions. However, due to the current physical and manpower constraints of the SAR environment, the HMI should be simplified considerably and many of the functions should be automated.

Alternative concepts for the ALBEDOS HMI are discussed. It is recommended that the proposed concepts for the HMI be prototyped and evaluated by potential users. In some cases, functions were not tested sufficiently because of time constraints and inexperience with ALBEDOS. Thus clear recommendations for controlling those functions could not be made. In those cases, suggestions for further evaluations are presented. In addition, feasibility studies should be carried out on automating the focus, linking the laser illuminator range to a laser range finder, and adding an automatic scanning capability and an automatic detection and tracking capability.

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1. INTRODUCTION

1.1 Background

An Airborne Laser Based Enhanced Detection and Observation System (ALBEDOS) has been developed by WestCam Inc. under contract to Defence Research Establishment Valcartier (DREV). The purpose of the system is to enhance the surveillance capability at night and under degraded weather conditions. The system is currently being developed for Search and Rescue (SAR) operations. However, it is anticipated that ALBEDOS will be useful to other agencies conducting surveillance operations (e.g. Coast Guard, RCMP).

Currently, there are several systems available to enhance the visibility of objects under degraded viewing conditions. These include high performance cameras, light intensifiers, and infrared cameras. All of these systems are passive and require at least some level of ambient illumination or radiation to construct a visual image of the scene.

ALBEDOS differs from these systems in that it is an active imaging device which does not require much ambient radiation. It consists of a pulsed laser source, a range-gated, intensified, CCD camera with a zoom lens, and associated electronics to synchronize the laser and the camera gate and to provide a wide selection of gatewidth, pulsewidth, and delays. The laser is used to illuminate the scene in a specified direction at a specified distance. The CCD camera gate is closed from the start of the laser pulse until twice the time it takes the laser pulse to travel out to the distance specified by the operator. The gate then remains open for a duration corresponding to the depth over which the operator wants the scene illuminated and then closes again. In this way, only the light reflected off objects at the specified range and depth enters the camera. A description of the system is available in Reference 1.

1.2 Human-machine interface (HMI)

Schematics of the interface for ALBEDOS are shown in Figures 1 and 2 and a description of the functions can be found in Appendix A. The interface allows the operator to view images from the camera and control the operation of the camera, laser illuminator, and gyro stabilized platform. Some feedback is provided on the console, but most of it is shown on the normal operation overlay (Figure 1).

As can be seen, the interface is quite complex. This occurs in part because the interface is an adaptation and extension of an interface for a simpler system and because no effort has been made to develop an interface specifically for ALBEDOS. Second, the system is a prototype and the developers wanted access to all the system parameters to thoroughly test out the technical capabilities and limitations of the system.

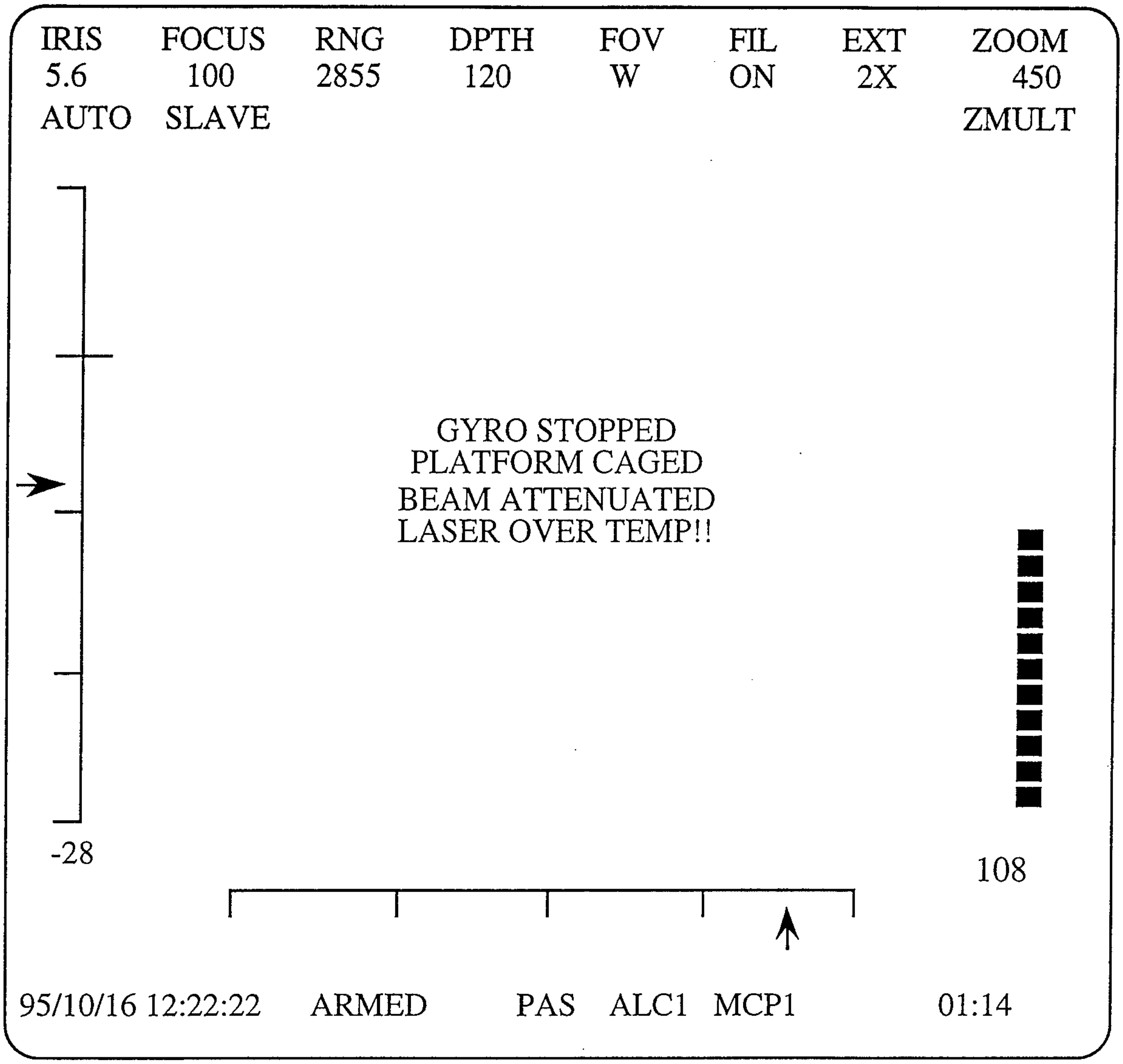
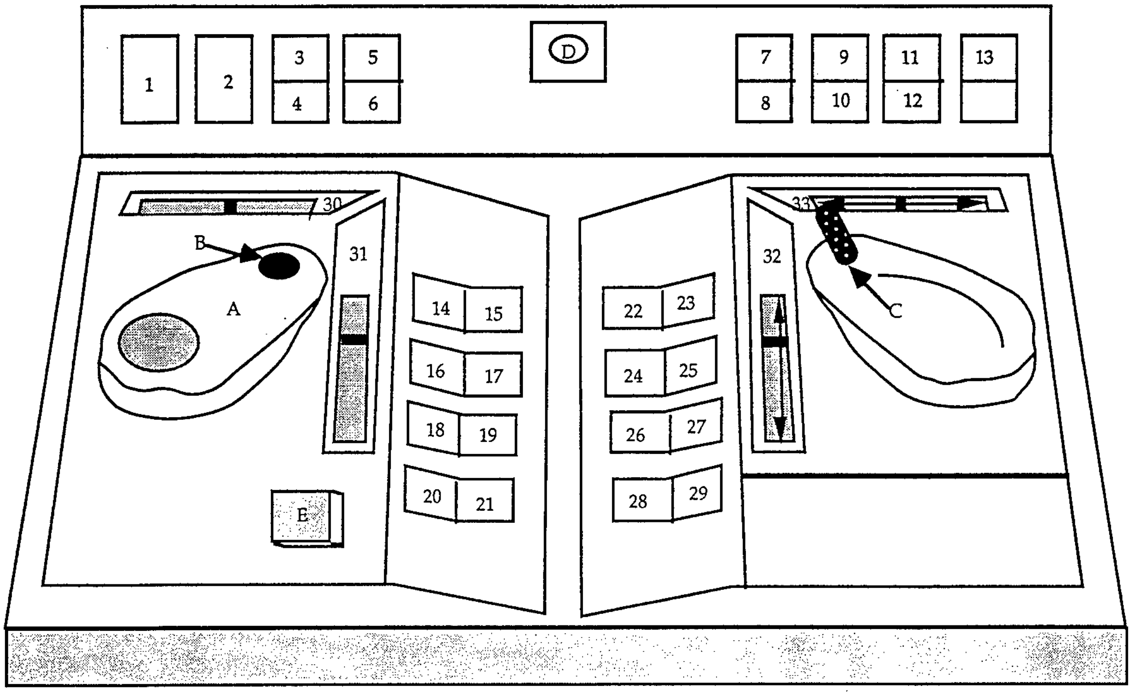


Figure 1: Schematic of normal operation overlay. The text in the centre of the screen are warning messages that appear only when necessary.

1.3 Evaluation of the Human-Machine Interface

In anticipation of problems with the existing interface, the Defence and Civil Institute of Environmental Medicine (DCIEM) was requested to assist in the development of a more suitable interface which would allow operators to conduct their tasks effectively and efficiently. Other design goals were to reduce mental workload and fatigue. These factors are especially important in the surveillance environment where the operators may have to use the system for long periods of time and/or under high stress levels.



1. LASER ON/OFF	2. LASER OVER TEMP	3. EXT 1X/2X
4. ZMULT	5. AUTO IRIS	6. FILTER
7. VEH SLAVE	8. VEH SLAVE SET	9. MODE
10. OVERLAY SET	11. GYRO ON	12. RAPID ERECT
13. SYSTEM ON	14. IRIS +	15. IRIS –
16. ALC +	17. ALC –	18. RANGE +
19. RANGE –	20. GATE +	21. GATE –
22. MCP +	23. MCP –	24. ALC AUTO/MAN
25. MCP AUTO/MAN	26. ILLUM FOV	27. FOCUS SLAVE
28. ACTIVE/PASSIVE	29. STATUS	30. IRIS (OPEN - CLOSED)
31. ZOOM (TELE - WIDE)	32. TILT (UP - DOWN)	33. PAN (L - R)
A. Zoom control	B. Focus control	C. Pan and tilt control
D. Key for laser on	E. Emergency switch for laser	

Figure 2: A schematic of the ALBEDOS console. The numbered labels appear on the console in the positions indicated. The alphabetic labels are provided to identify the remaining controls. Those labels do not appear on the console.

To meet these design objectives, the procedure in Figure 3 for system design is usually followed:

Preliminary review of system

↓

Operational needs analysis (task analysis)

↓

Which functions to incorporate (function analysis and allocation)

↓

Application of standards, guidelines, etc. for design and recommend HMI

↓

Develop prototypes

↓

Operators to test out prototypes with representative tasks
(gathered from previous task analysis)

↓

Decide which option from test of prototypes

↓

Final field trial

Figure 3. Adapted model from Checkland's emerging methodology diagram. (2)

Ideally, the information required for the task analysis would be gathered through interviews with a range of users and through extensive observation of the system in use under operational conditions or in specially developed scenarios. The results of the task analysis would be used to determine which functions should be allocated to the human and the machine. The results of this analysis, together with a review of applicable guidelines would point to design recommendations for the HMI. These design recommendations would include:

- what information should be available,
- how the information should be displayed,
- the controls required for each function,
- how the controls should be grouped, and
- the functions that should be automated.

However, a formal task analysis was not possible for ALBEDOS, because it is a prototype and many sources of information were not available. In an attempt to capture information normally available from a task analysis, the following evaluation was carried out:

- an initial meeting with SAR personnel,
- a pen and paper review of the functionality of the HMI,
- observations of the operators' actions during preliminary trials of ALBEDOS, and
- structured interviews with participants in the trial before and after they had used the system.

This report presents the results of the above evaluations and uses the information to make HMI and allocation of functions design recommendations. Where insufficient data were available, suggestions are made for additional evaluations. The HMI design recommendations should feed into the rest of the process outlined above. The allocation of function suggestions are intended to provide direction for future development of ALBEDOS. Thus the HMI recommendations assume the current level of automation. Since the scope of the evaluation is limited, the recommendations primarily reflect the requirements for SAR operations and may not be suitable for other applications.

2. METHOD

2.1 Participants

The participants were three pilots flying SAR helicopters and one Aurora airborne electronic sensor operator. All of the participants had been in the military for 20 years or longer and had extensive experience in SAR operations including experience with a wide range of operations, scenarios, terrains, and targets. None had used the system prior to this preliminary trial. In addition, the questionnaire was completed by an experienced user of the system who had been involved in its development to gather some information on how the responses of an experienced user might differ from our inexperienced participants.

2.2 Functional review

The over all HMI and the controls and displays for the various functions were evaluated using MIL-STD-1472D, *Human Engineering Design Criteria for Military Systems, Equipment, and Facilities* (3).

2.3 Structured Interview

A questionnaire was developed to solicit the opinions of the participants in the preliminary trials about the potential usefulness of ALBEDOS, the problems they had encountered in using the interface, and ways of improving the interface. The questionnaire was divided into three sections. The first section was given prior to the operators using the system. The purpose was to gather background information on the participants and to ascertain whether there was a requirement for this type of system and what characteristics it should have. Since all of the participants had received at least an initial briefing about the system, they had some general knowledge of its function and capabilities. This knowledge may have influenced the responses in the first section.

After flying a scenario with ALBEDOS, the participants were given the second section which repeated the general questions about the system. However, the participants were asked to comment on the use and usefulness of the specific system that they had just used rather than a generic system.

The third section consisted of a series of questions on each of the functions available on the system. Although the precise questions varied somewhat from function to function, the main factors addressed were:

- usefulness,
- frequency of use,
- suitability of the controls,
- usefulness of the information or feedback provided,
- whether or not the function should be automated, and
- suggestions to improve the HMI.

The questionnaire is too extensive to replicate here, but it is available on request.

2.4 Procedure

The initial step in this evaluation was a meeting with SAR personnel to brief them on the system, to solicit scenarios for testing out the functional capabilities of ALBEDOS, and to obtain some initial opinions on the potential uses of such a system.

Several scenarios representative of the kinds of activities that the SAR personnel might be involved in were developed. These scenarios were carried out over a three day period to assess the technical capabilities of ALBEDOS. Details about the trial and the scenarios can be found in Reference 4. All scenarios were carried out at night under clear or slightly overcast skies. Each of the four military personnel carried out one or more of these scenarios over the three day trial. As well as evaluating the system, the participants compared its capabilities with those of the night vision goggles (NVGs) that they currently use for searching at night. Since the use of NVG's was unplanned, the relative value of NVGs and ALBEDOS was not addressed in the interview.

The questionnaire was given to the three SAR participants in the form of a structured interview with each participant being interviewed separately the day after his flight. The other two participants completed the questionnaire on their own after the field trial.

2.5 Data collection

The current ALBEDOS system is extremely flexible, allowing access to all functional capabilities. Consequently, the operators often had trouble operating such a complex system. It also meant that they did not systematically test many of the functions.

In addition, it was not possible to make extensive observations when the participants were using the system, because of limited space in the helicopter. The unplanned use of NVGs during the trials also affected the nature of the opinions provided by the participants. Also, the evaluator could not listen in on the conversation between the observer with the NVGs (in the co-pilot's seat) and the ALBEDOS operator in the back.

These factors limited the quantity and quality of the information that we were able to collect during the interviews. Thus, the evaluation of the HMI data was based on a combination of:

- the review of the functionality of the system,
- the structured interviews, and
- the video recordings of the contents of the screen during the trials.

No quantitative analysis of the data was carried out because of the limited number of participants.

3. RESULTS

3.1 Static functional review of the interface

The following sections present observations on the suitability of the HMI of ALBEDOS according to guidelines set out in MIL-STD-1472D.

3.1.1 Overall layout:

MIL-STD-1472D requires that primary functions be located in the centre of a console and the associated information displays be located in the centre of the operator's field of view.

There are three main functions that must be carried out on a continuing basis to use the system to detect and identify targets:

- manipulation of the camera direction (pan and tilt),
- manipulation of the focal length of the lens (zoom), and
- manipulation of the distance from the camera at which the scene is illuminated (range) and the size of the illuminated area (depth and field-of-view).

Most of the controls for these functions are located in the main part of the console. There are, however, several other controls that are located in the same area which are identical in shape to the controls for the range and depth. For example, the control for bringing up the status overlay and the control for turning the laser illuminator on and off are on opposite sides of the same toggle switch. This location makes the two controls subject to confusion. Evidence for this was the occasional brief selection by operators of the status and mode overlays, due probably to accidentally selecting the wrong button. With the current system, it is only possible to detect and track targets if the operator is looking at the screen. If the operator has to attend to the console in order to select the appropriate control, then he or she could miss targets.

MIL-STD-1472D requires that controls and displays associated with a specific function should be grouped together.

There are a few cases where this rule has been followed with ALBEDOS (emergency information is grouped in the center of the screen). However, as shown in Figure 2:

- the controls for adjusting the range and depth are grouped with those for controlling the aperture and the image intensifier offset while the control for changing the laser illuminator field-of-view is on the opposite side of the console,
- the feedback on the status of the controls for the camera and the laser illuminator are interspersed, and
- the information about the zoom is grouped together on the right hand side of the screen and the controls for the zoom are on the left hand side of the console.

This configuration makes it difficult for an operator to control the functions without looking down at the console. In addition, some of the feedback for the camera functions are located on the console, which also requires the operator to take his or her eyes off the screen.

MIL-STD-1472D requires that redundant information be avoided unless absolutely necessary.

ALBEDOS provides:

- three different displays of the status of the pan, tilt, and zoom
- two different displays for the status of the iris.

In the case of the zoom, pan, and tilt, a single graphical display for each function would suffice, if they were adequately labelled.

In comparison, needed information is not provided about the image intensifier offset and gain or about the status of the vehicle slave mode.

MIL-STD-1472D requires proper labelling.

Again, proper labelling should make the need for the information on the status of the optical extender for the zoom redundant, especially if a proper toggle or rocker switch is used to insert or remove the extender instead of the current control.

3.1.2 Controls:

MIL-STD-1472D provides guidelines on which types of controls should be used and on which types of controls should be used with different types of functions: If a parameter or function can be adjusted continuously, then some type of continuous control is recommended.

The ALBEDOS functions that can be adjusted continuously are the:

- pan,
- tilt,
- zoom,
- focus,
- aperture size,
- laser illuminator range and depth, and
- the image intensifier offset and gain.

Continuous controls are used only for the pan, tilt, zoom, and focus. The remaining functions can be adjusted continuously only by pushing and holding down the appropriate button. This type of control allows very coarse adjustments only. Thus the user must follow up the coarse adjustment by pushing the button discretely. This can be very time consuming. Moreover, having to hold down a button continuously is fatiguing. Controls similar to those employed for the pan, tilt, zoom, and focus would be more appropriate.

MIL-STD-1472D requires the use of a joystick for tasks requiring precise or continuous control in two or more related dimensions. It suggests the use of an isotonic (displacement) joystick over an isometric (pressure) joystick when positioning accuracy is more critical than positioning speed.

If the system is to be used primarily for zeroing in on a particular target, the recommendations of MIL-STD-1472D would favour an isotonic joystick over the isometric joystick currently used for adjusting the direction of the camera. However, a review of six studies comparing tracking error with displacement and pressure joysticks found consistently smaller tracking error with pressure joysticks (5).

The pressure knob used to control the zoom is acceptable based on MIL-STD-1472D. However, it is not clear that a rotational control is consistent with the zoom function. The zoom can be seen as increasing and decreasing the size of the image. Turning the knob is one direction increases a parameter and turning it in the other direction decreases it. Although this is consistent with adjusting photographic camera lenses, the zoom could also be seen as going towards or a way from an object. In that case, a vertical continuous control would be more consistent with the function. It would also be more consistent with the graphical display which is a vertical line that increases and decreases.

MIL-STD-1472D recommends rocker or toggle switches for two-state functions such as:

- turning the system on and off,
- activating the gyro,
- turning on automated processing,
- inserting the filter,
- inserting the optical extender,
- changing the field of view.

Although the discrete controls used on the ALBEDOS console look like rocker switches, they are not implemented as rocker switches. Each half of the switch acts like a discrete push button. Pushing the half of the rocker switch labelled "ACTIVE/PASSIVE" switches the laser illuminator from passive to active mode, but that side of the switch does not stay depressed. To switch the laser back to passive mode, the operator must push the same side of the rocker switch again.

To conform with MIL-STD-1472D, all of these functions should be controlled by true rocker switches or equivalent. Depressing one side of the rocker switch would activate that function (e.g., the laser); pushing the other side would change the position of the rocker switch and deactivate that function (e.g., the laser). The operator would thus receive clear feedback from the switch indicating that the intended action was implemented (even if the event did not occur) and ongoing feedback about the status of that function (e.g. if the laser illuminator turns off, the operator can tell if it was or was not due to someone accidentally pushing the switch).

MIL-STD-1472D requires that emergency controls be readily accessible but be laid out in such a way that they cannot be activated accidentally, if the consequences of the activation are disastrous.

The emergency button to disable the laser is located at the bottom of the console slightly left of center. Since the button is well removed from the other function buttons, an operator is not likely to select it by mistake. However, it might be possible to hit it accidentally while reaching for another control or while resting on the console. As well, the button is not labelled in any way and could be activated by mistake by someone unfamiliar with the system.

3.1.3 Displays:

MIL-STD-1472D requires that feedback should be consistent with the control.

Up-down pressure on the joystick is associated with up-down movement of the position indicator for the tilt and similarly left-right pressure is associated with left-right movement of the position indicator for the pan. The use of two separate displays to provide feedback for a single control is a potential problem. The operator must integrate the information in his mind in order to decide where to push the joystick next.

As stated earlier, the rotational movement of the zoom control is associated with a vertical movement of a bar on the screen. A horizontal bar graph would be somewhat more consistent with the control but not necessarily consistent with the concept of zooming in and out.

MIL-STD-1472D states that scale indicator displays should be used to supply quantitative information in combination with qualitative information.

This specification implies the use of alphanumeric labels on position indicator displays etc. None of the scales or bar graphs on ALBEDOS are labelled. There are numerical readouts that give the horizontal and vertical position of the camera relative to the nose of the aircraft and the focal length of the camera lens, but they are spatially separated from the position indicator scales and the bar graphs. To meet the specification, all the displays should have alphanumeric labels at regular intervals along the scale.

3.1.4 Special Issues:

We had concerns about the HMI of some specific functions, in addition to the interface issues discussed above. For example, the operator must hold down the "RAPID REACT" control button until the operation is complete (which can take several minutes). This is time consuming, fatiguing, and distracts the operator from the main task. A second problem with this function is that the normal operation overlay is replaced with the status overlay which covers the whole screen. While the camera image may not be optimum under these conditions, it still may provide useful information and should not be obscured unless absolutely necessary.

A second issue is the "FOCUS SLAVE" function which, when activated, allows the operator to use the focus control knob to adjust the laser illuminator range. A single control for two discrete unrelated functions is not recommended. If the operator uses this function, he or she will have to remember that it is enabled or will have to check the screen before trying to change either the focus or the range. For example, if the operator tries to adjust the focus after zooming in on a target and adjusted the range instead, the target could be lost.

In some cases, it could be difficult to determine the meaning of certain terms on the screen without prior knowledge. For instance, "FOV" (field-of-view) would intuitively seem to be related to the camera and not to the width of the laser illuminator beam.

3.2 Participants reaction to ALBEDOS

The following section summarizes the participants' overall impressions about the potential usefulness of ALBEDOS and the strengths and weaknesses of the HMI.

3.2.1 Potential application of ALBEDOS:

Initially, all of the participants thought that a system such as ALBEDOS would enhance their SAR capability. After using the system, the participants felt that its primary use would be for identification. As it is currently configured, they thought that it was of limited value for searching large areas.

Based on their responses, the primary limitations facing SAR operators are:

- reduced visibility,
- darkness,
- lack of electronic aids,
- the size of the area to be searched, and
- limited capability to fly at night.

These limitations are consistent with the findings of a system analysis on the SAR helicopter (6).

All four of the military participants felt that a system such as ALBEDOS would help them identify targets at night or in degraded weather conditions, especially for non-cooperative targets (without signaling device). Currently, their night navigation capability is limited, such that to identify a target, they must go into a low hover. However, they did not think that ALBEDOS would enhance their search capability to any great extent because of its limited field of view.

The most useful part of the system for the participants was the laser illuminator. They felt that it would increase their detection ranges and their ability to detect targets, especially those with retroreflective tape. However, there seemed to be a consensus that the laser illuminator would be most useful if used in conjunction with NVGs rather than the CCD camera, especially if the area illuminated by the laser could be increased. (The U.S. Coast Guard uses two beams concurrently for this purpose.)

3.2.2 Functional requirements for a system such as ALBEDOS:

The SAR operators stated that a system such as ALBEDOS should be small and compact and should not required a dedicated operator.

There is very little extra space in the SAR helicopter and all of the crew are heavily tasked already. It would not be possible to dedicate a single crew member to operating the system or to add another crew member for that purpose. To meet these requirements, they recommended that the system should be highly automated. Some of the features that they thought might be automated included scanning, detection, and tracking. However, they thought that all automated functions should have a manual override for special situations. In terms of capability, they felt it should have a wide field of view for search mode and more extensive zoom capability. Detection ranges of 1 NM over land and 5 NM over water were recommended by one participant.

3.2.3 Operability:

All the participants found the system fatiguing to use and the work involved in operating the system excessive.

They found it difficult to locate targets even when they knew where the targets were and to keep them on the screen, especially when zooming in or out. They also found it difficult to keep track of where the camera was pointing. They all felt that it was necessary to constantly keep their eyes on the screen. Thus, any actions that required them to take their eyes off the screen tended to receive a negative evaluation. This usually occurred when they had to use one of the function buttons.

Participants made positive comments on the following:

- the detection range of the system,
- its ability to zoom right in on a target,
- the responsiveness of many of the analog controls, and
- the ability to resolve small details.

To make ALBEDOS even more effective, participants felt it should have the following:

- a wider field of view,
- more zoom capability,
- a clearer indication of the camera's position, and
- some way of automatically setting up the range.

3.3 Dynamic review of the interface

The following section summarizes the participants' comments on the specific aspects of the HMI and the authors' observations from the videotape.

3.3.1 Frequency of Use of Controls:

The participants considered most of the functions that they used to be important to the successful operation of ALBEDOS. Based on their comments and our observation of the video tapes, the most frequently used functions were the:

- pan — moves the camera in the horizontal plane,
- tilt — controls the movement of the camera in the vertical direction,
- zoom — varies the size of the area on the screen and the resolution of the image,
- laser illuminator range — controls the distance between the camera and the start of the illuminated area.

Less frequently used functions include the following:

- size of the illuminated area (depth),
- camera focus and aperture opening,
- zmult, and
- field of view of the laser illuminator.

3.3.2 Pan and tilt:

The participants had little or no trouble operating the joystick that controlled the camera position:

- One participant expressed a preference for a position joystick rather than the pressure joystick;
- a second felt that the camera did not respond fast enough during turns.

Participants had serious concerns about the information provided on the camera position:

- They primarily used the position indicator displays on the screen; looking at the position indicator on the console would have required them to take their eyes off the screen and they tried to do that as little as possible.
- They did not find the position indicator display on the screen provided sufficient information and were often confused about which direction the camera was pointing relative to the aircraft.

Participants made several suggestions to improve these displays, including:

- using a bar graph on the screen rather than the position indicator,
- annotating the position indicator with labels showing which angles were associated with the back, front, and side of the aircraft, and
- replacing the current displays with a silhouette of the aircraft with the direction of the camera highlighted.

Most of the participants favoured automating the pan and tilt under specific conditions:

- Three of the four participants thought that the movement of the pan and tilt could be automated under specific conditions;
- one of the participants recommended that the pan and tilt operate in automatic mode during the scanning process;
- two others recommended an automated tracking capability.

3.3.3 Zoom:

None of the participants expressed any problems in adjusting the zoom. However, they did indicate that it was difficult to keep the camera on the target when they were zoomed in.

There was a difference of opinion on the suitability of the range of the zoom: one person thought it was sufficient while two others thought it should be greater. A review of the videotapes of the flight indicated that the zoom was used most frequently without the optical extender inserted (the 1X mode). This might have contributed to their impression that the zoom range was inadequate. To insert the optical extender, they had to push one half of a rocker button on the upper left hand side of the console. This would have required them to look away from the screen. Moreover, being fully occupied with the task, they may not have remembered that the range could be increased in this way.

Most expressed satisfaction with the information or feedback provide on the zoom position.

Participants stated that they primarily used the bar graph on the screen to get feedback on the position of the zoom.

There was no interest in automating the zoom function.

Most felt that the zoom had to be maintained under manual control.

3.3.4 Laser illuminator range:

In general, the participants found the control for the laser illuminator range difficult to use and inappropriate.

Based on observation of the tapes of the screen output during the trials and the participants' comments, they only used the rocker control to change the range. If they pushed the button discretely, the rate of change was too slow. If they held it down, the rate was too fast so that they often overshot the range they wanted. In order to operate these switches, it was necessary to stop controlling either the zoom or the pan and tilt. Some of them found this unsatisfactory. The most frequently recommended solution was to automate the range control. There was also one recommendation for a rotary control.

The weather was reasonably clear during all the trials, making it possible to leave the camera gate open over an extended duration and the depth between one and two kilometres. This meant that as long as the range was shorter than the distance to the ground, it was probably adequate. If the selection of the range had been critical, the operators might have encountered even more problems with the interface than they did.

The experienced user reported using the "FOCUS SLAVE" to control the laser illuminator range. He found that if one tried to adjust the focus while in this mode the range was too far away. This indicates that both the focus and the range changed when the focus control was adjusted in the "FOCUS SLAVE" mode.

The participants thought that the range information could be improved upon.

When the range was being adjusted, they found the numbers changed too fast to read them. This contributed to their difficulty in setting up a particular range. Moreover, they are most familiar with nautical miles, which the aircraft uses, and they found the metres difficult to interpret. It was recommended that the numbers should be in the same units as employed in the aircraft. Overall, the preference was for some type of bar graph.

All of the participants recommended at least partial automation of the range.

They thought that it should not be necessary to make large adjustments to the range except under specific circumstances. Thus, the range should be linked either to the aircraft altimeter or to a laser range finder. Once the general range had been determined by these methods, minor adjustments could be made manually if necessary. The experienced user of the system suggested adding an automated scanning capability to the range for use when searching for a target.

3.3.5 Laser illuminator depth:

The participants comments on the depth control and display were similar to those for the range.

As with the laser illuminator range, the participants commented that it was difficult to handle this activity in conjunction with all the others. However, they did not find the depth as difficult to handle as the range. This difference could have been due to the depth being used less frequently than the range. The weather was relatively good throughout the trial making it possible to operate the system with a long depth. There was not much interest in automating this function. One participant commented that he could not see how the system could determine what depth the operator wanted. They thought it was better to automate other functions.

3.3.6 Focus:

The participants expressed no difficulty in adjusting the focus. All of them thought that it should be automated with a manual override capability.

The focus was usually adjusted only when the participants zoomed in. Even then, the video tapes indicated that it was rarely moved away from infinity. The participants stated that the information on the focus had little meaning for them. The only thing they could interpret from the readout was whether the focus was at infinity or not. The primary feedback came from the image itself. Most felt that the only information required was whether the focus was at infinity. The experienced user reported adjusting the focus more frequently than the inexperienced participants. He thought that the focus control should be less sensitive especially at long focal lengths and that feedback should be provided for distances between 20 metres and infinity.

3.3.7 Aperture size:

The primary comment about the aperture size was that one had to take one's eye off the screen to adjust it.

Only one of the participants reported significant problems in controlling the aperture size. However, based on their comments and a review of the video tapes, it was adjusted infrequently. Again the experienced user reported more frequent use of the aperture control than the other participants.

The participants did not find the aperture size information very useful.

The participants used only the numeric readout on the screen despite the fact that none of them found that output useful. Most expressed a preference for some type of analog display such as the bar graph on the console.

Most of the participants felt that control of the aperture size should be automated with a manual override for unusual situations.

Most of the participants claimed to have controlled the aperture size manually and the video tapes support that claim. This could have resulted from unfamiliarity with the system. If the function had been put in automatic mode at the start, they probably would have left it that way.

3.3.8 Zmult function:

Most of the participants found it useful.

Most of the participants claimed to have had the zmult on for a significant amount of the flight; the video tapes support the frequent use of the zmult. However, they did feel that not being able to move the camera quickly when it was zoomed in could be a problem. Based on some of the comments, it would appear that the participants required more experience with and without the zmult to assess its importance.

3.3.9 Vehicle slave function:

Further experience with the vehicle slave function is required to assess its potential usefulness. However, feedback on the status of this function should be provided.

Only one of the naive users and the experienced user reported using this mode. The participant thought that it was a useful and usable function, but that there were certain drawbacks. It allowed the user to return to an established reference point if he became confused about where the camera was pointing. On the other hand, it was often necessary to remove one's hand from the joystick to access another control. This could result in a target being lost as the camera returned to its home position.

The experiences of the other participants with the system support these observations. Most of them complained about having difficulty keeping track of the direction the camera. This difficulty could be overcome by having the home position looking straight ahead in the direction of the aircraft nose. The participants also complained about not having enough hands to carry out all the functions. Thus, one could anticipate a situation in which having located a target, the operator takes his hands off the joystick to adjust the range or depth to get a better image and the camera swings back to its home position.

Both users of the vehicle slave function thought that information about the vehicle slave mode and the home position of the camera were very important.

3.3.10 Display direction of contrast:

There was no clear pattern of responses to this.

Most of the participants reported using the full white overlay most of the time. However, a review of the video tapes indicated that two of the participants used the black overlay throughout their flight. The third used the black overlay on his first flight and the white on the second flight (after being interviewed). Thus, the value of some of their responses to the questions on the overlays is questionable. Two of the participants thought having the six overlays somewhat useful and the other two thought it was very useful. However, given that they never changed the overlays during a flight, this conclusion is questionable.

The experienced user recommended removing the partial overlays and at least one of the overlay-off modes. He felt that he wanted as much image information as possible at all times.

3.3.11 Brightness of the screen overlays:

Most participants commented that some of the alphanumerics were washed out by the underlying image. They suggested that the luminance (black or white) of the alphanumerics should change automatically, as a function of the average luminance of the underlying image.

A review of the video tapes supported the participants concern about washout. However, it was often confined to part of the overlay. On the whole, the white display was best during search when the operator was not zoomed in on a target. Under those conditions, the background on the edges of the display was usually dark. When the camera was zoomed in, the illuminated area often filled the screen washing out some of the white letters. Under those conditions the black overlay was more readable.

The participants were asked if a function to adjust the brightness of the alphanumerics independent of the underlying imagery would be useful. Except for the experienced user, there was only mild interest in such a function.

3.3.12 Other functions:

The participants did not report any problems with the controls for the remaining functions and found the information provided satisfactory.

Most of the remaining functions were used infrequently or during the initialization phase only.

4. DISCUSSION

If ALBEDOS is to be successful, it must significantly improve the capabilities of SAR personnel to carry out their mission. Based on the general comments of the SAR operators, ALBEDOS could enhance their capability to identify targets at night and under degraded weather conditions. However, based on the operational constraints of the SAR environment, the system as currently configured is too labour intensive and probably too bulky.

4.1 Design of interface

Based on the experiences of the participants, the primary goals in developing the interface should be:

(1) to keep the operation of the system as simple as possible,
(2) to ensure that the operator can keep his or her eyes on the screen as much as possible (since searching is main task).

To meet both objectives:

- controls should be grouped according to function,
- only critical information should be presented continuously,
- a display should be consistent with its corresponding control, and
- displays and controls should be consistent with the intended functions.

In addition, to meet the second (2) objective:

- the controls should be designed and located so that they can be discriminated and identified by touch and spatial position, and
- all critical information should be presented on the screen.

As stated in the results, the main functions carried out by the operator were:

- controlling the direction of the camera,
- controlling the zoom,
- controlling the range of the laser illuminator, and to a lesser extent,
- controlling the depth.

Less frequently used functions can be grouped into those associated with:

- the camera (rapid erect, zmult, vehicle slave mode),
- the zoom (optical extender),
- the laser illuminator (activating the laser, field of view),
- the image on the screen (focus, aperture, filter, image intensifier offset and range), and
- the initialization functions.

As stated in the introduction, the results of this analysis are intended to guide the design of the prototype(s). Thus the following discussion frequently suggests alternative controls and displays. In some instances, insufficient experience with a function makes it difficult to make a concrete recommendation. For those functions, suggestions for further evaluations are made.

4.1.1 Camera interface:

Some form of two-dimensional joystick should be used to control the direction of the camera. The discrete function controls associated with the camera operation should be located either on the joystick or accessible by either hand.

Based on the operators comments and observation of the video tapes, the operators rarely let go of the joystick. Thus, if the hand controlling the joystick is to control any other function, that function should be on the joystick. To avoid confusion with the primary task, the actions controlled this way should be discrete. Moreover, the functions should relate to the control of the camera, to maintain the overall goal of functional grouping. Functions that fall into that category are the zmult, the vehicle slave mode functions, and the rapid erect function. If these controls cannot be located on the joystick, they should be positioned so that they are accessible by either hand, in case the operator is unable to let go of the joystick. Since setting up the vehicle slave mode is not a two state function, a simple push button is appropriate. If possible the rapid erect function should be initiated by a push button control as well, and should terminate automatically when the stabilizers have returned to horizontal. If this is not feasible, then a two-position switch should be used. The remaining functions should be controlled by two-position switches or rocker buttons.

If a two-dimensional display is not feasible, then labelled horizontal (pan) and vertical (tilt) bar graphs should be used to indicate the direction of the camera.

Based on the participants' comments, the most suitable display for the pan and tilt would be some form of two-dimensional display. However, in order to minimize interference with viewing the image, information must be restricted to the edges of the screen. It may be difficult to design a suitable two-dimensional display within that constraint. The alternative is a graphical display similar to what is currently used.

The participants found the position indicator display difficult to read and interpret. A form of bar graph would seem preferable with the zero point on the graph being the zero position for the camera (pointing straight ahead and towards the nose of the aircraft). If the camera deviated from that position, the bar would increase in size in the direction of the moving camera. The bar graph should be labelled at 30 degree intervals. There would be a horizontal bar graph for the pan along the bottom of the display and a vertical bar graph for the tilt on the same side of the screen as the control is on the console.

Feedback for the vehicle slave mode functions should be placed on the displays for the pan and tilt. An alphanumeric mnemonic (that appears when a function is enabled and close to the pan and tilt display) should be used to provide feedback for the zmult and rapid erect functions.

Since the status of these functions impacts on the operator's control of the camera, feedback is desirable. The operator-selected home position for the vehicle slave mode could be marked on the display for the pan and tilt. Activation status could then be indicated by modifying the markers that show the home position.

4.1.2 Zoom interface:

A continuous control consistent with the concept of zooming should be used for the zoom. It should be located on the opposite side of the console from the primary control for the camera. A labelled control for the optical extender should be located close to the zoom. It should be a toggle switch or rocker button.

As with the pan and tilt, a continuous control should be used for the zoom. To avoid confusion with the control of the camera, the other hand should be used. During the trials, the participants zoomed in when it was necessary to identify the target and zoomed out when the target was lost or to search for a new target. To accomplish this task quickly, the zoom should be reasonably fast. However, if it is too rapid, the operator may lose the target in the process. Depending on the size of the target, it may be necessary to make relatively small adjustments to the zoom. Given the complexity and ambiguity of the task, alternate controls that are consistent with the tasks and the concept of zooming should be investigated.

The display for the zoom should be located on the same side of the screen as the control is on the console and should be consistent with the direction of movement of that control.

It is preferable if the direction the bar graph and the control move are consistent. Thus if a rotary control is used, a horizontal bar graph should be provided. If the graph is properly labelled, it should not be necessary to provide alphanumeric information on the actual focal length. The operator needs to know approximately how much he is zoomed in, not what the current focal length is. Moreover, if the minimum and maximum values indicate the current range of the focal length, additional alphanumeric information on the screen on the state of the optical extender is not necessary.

4.1.3 Laser illuminator interface:

The controls for the laser illuminator range and depth should be located on the same side of the console as the zoom control. Continuous controls that are discriminable from each other and from the zoom control by touch and spatial location should be used.

The laser illuminator range, in contrast to the zoom, is usually manipulated while the operator is searching for or moving in on a potential target. Thus it could be controlled by the same hand as the zoom and located on the same side of the console as the zoom. The distance over which the range can be varied is relatively large. In the SAR application, it is usually governed by the aircraft altitude and the direction the camera is pointing. If the camera direction is changing rapidly, it may be necessary to make relatively large adjustments to the range, especially if the depth is short. The depth depends on the weather conditions. The more overcast the sky is, the smaller the depth must be to optimize signal to noise ratio. Since weather conditions are unlikely to change rapidly, it will probably be adjusted frequently initially to achieve the best signal to noise ratio and infrequently thereafter.

The most suitable control for these two functions should be investigated. To enable the operator to select the appropriate control without looking away from the screen, the range and depth controls should be discriminable from each other and from the zoom by touch and by location. The depth and range could be made discriminable by using a large knob for the range and a smaller knob for the depth.

Either one or two, labelled, graphical displays should be used to provide feedback on the range and depth.

If a rotary control is used for adjusting the range and depth, a horizontal bar graph would be preferred. Since the depth is the distance beyond the range distance that is illuminated, both functions could be presented on a single graph with different coding. One problem with this solution is that one display is used to present feedback on two discrete controls. To assess whether this is a problem, a one- and two-graph concept should be prototyped.

Labelling the graph(s) is essential to provide feedback on the actual distance. However, a numerical readout might be appropriate as well, so that the operator can correlate the range with the aircraft altitude and the depth with recommended depth for the weather conditions. To simplify these comparisons, the readouts should be in nautical miles. A potential problem in designing this type of display is the large range available. Detection ranges of up to 10 km are anticipated. A simple linear display may be inadequate and alternate methods for displaying such large ranges in a limited display space should be explored.

Labelled, two position, switches , located close to the range and depth controls, should be used to control the discrete functions associated with the operation of the laser illuminator.

Activating the laser and changing its field of view are functions that affect the operation of the laser illuminator, but are carried out infrequently. Activating the laser can be seen as the last step in the initialization process. However, the operator may want to turn the laser off under certain conditions and operate with the CCD camera alone. Thus it may be appropriate to locate it either in conjunction with the initialization functions or in conjunction with the controls for the range and depth. Changing the field of view, like changing the depth, affects the size and brightness of the illuminated area. Thus, it is reasonable to locate that switch in the vicinity of the range and depth knobs.

Suitable feedback for the status of the laser and the field of view should be investigated.

Some kind of feedback on the status of the laser and the field of view should be available on the screen. In the case of the laser status, a mnemonic similar to what is currently used is probably reasonable. For the field of view, one might consider alternating the width of the depth bar graph as a function of the field of view. Evaluation of this alternative would need to be investigated during prototyping.

4.1.4 Image quality functions:

Continuous controls should be used for adjusting the focus, aperture opening, and the image intensifier offset and gain. These should be located immediately below the monitor screen. However, alternative locations should be considered for the focus and aperture controls.

The focus, aperture, image intensifier offset and gain, and narrow band filter all affect the quality of the image on the screen. Currently, only the focus is adjusted by a continuous control. However, the aperture opening and the offset and gain can also be varied continuously and should be adjusted using continuous controls. The narrow band filter on the other hand, is either in or out. Thus a simple toggle switch is sufficient. Feedback is desirable, but most of the feedback will come from the image on the screen.

Based on the experience of the participants, these functions will probably be used infrequently and all except the focus and the filter can be used in automated mode. However, the experienced user did report adjusting the focus and aperture relatively frequently. If they are used infrequently, the controls do not need to be located near the center of the console. One possibility is to locate the knobs on the bottom of the CRT. If further investigation indicates frequent manual control of the focus and aperture size, a more accessible location should be considered for these controls.

The two position switches for changing from manual to automatic could be located below each knob for those functions that have an automated mode. Feedback on the status of the image quality controls should be provided only on demand and should be located immediately above the controls.

The participants could not make use of the feedback for these functions. In general, the primary feedback was the change in the screen image when an adjustment was made. Thus, there appears to be little benefit in having the current value of these functions continuously on the screen. An alternative would be to have the current value appear on the screen above the knob being adjusted, while it is being adjusted, and for a fixed period afterwards. If the knobs were labelled and close enough to the screen, then the mnemonics that currently appear on the screen should be unnecessary. If a knob was touched in the automated mode, the current value would appear, but it would not change.

4.1.5 Emergency switch:

The emergency switch should be in the center top of the console and recessed into the console so that it cannot be pressed accidentally. It should be labelled and light up when pressed.

The location of the emergency switch is critical. Its current position appears to be susceptible to accidental activation and not ideal for quick activation in an emergency. A preferred location would be in the center of the console above the analog controls so that it can be accessed with either hand, but would not be hit accidentally. The control should be clearly labelled, uniquely coded (i.e., by shape and location) to further reduce the possibility of accidental activation. Since hitting this button effectively removes the image, a message indicating what has happened should be shown in the center of the screen.

4.1.6 Initialization:

Controls for the initialization functions should be located at the top right hand side of the console, in the order used.

Most of the remaining functions are related to initialization and maintenance. Since these are carried out independent of the other functions, they do not need to be grouped with these functions. If possible, discrete controls should not be located below the continuous controls. Otherwise, the operator would have no place to rest his or her arm while operating the continuous controls without fear of accidentally hitting a switch. Thus, the initialization controls should be located at the top of the console; separated from the other functional groupings. Most of the initialization functions are two-state discrete functions. The exception is arming the laser. This key should be located so that the operator can comfortably access both the switch and the key for arming the laser simultaneously.

One limitation with the current system is that the laser can be in either active or passive mode when it is first armed. This is undesirable. There should be some sort of interlock to prevent the laser from being armed unless it is in the passive mode.

Continuous feedback on the status of the initialization functions should be provided through the position of the labelled two position switches only.

Continuous feedback on the screen is probably not required for either the power-on or gyro-on functions. However, it is important for the operator to be aware that the laser is armed. This can be provided through illuminating the laser-on switch and having the status of the laser appear on the screen only when the laser is armed.

4.1.7 Maintenance functions:

Maintenance functions should be accessed by a switch on the console and should be adjusted through soft controls on the screen.

On most systems, the maintenance mode is separate from the runtime mode. Maintenance functions cannot be carried out while the system is being operated and vice versa. This is not true with this system. The status overlay and mode overlay can be called up at any time while the system is in operation. This is not desirable. To correct this, a switch should be added to allow the operator to enter a maintenance mode. Since maintenance checks are usually carried out during start up, this switch could be located with the other initialization controls. Accessing the status and mode overlays and adjusting the parameters on the mode overlay would be carried out in this mode along with other maintenance activities. If at all possible, maintenance activities should be carried out through interaction with the screen to minimize the number of controls. For example, the operator could be provided with a list of available alternative actions that could be carried out and would select the desired alternative using a cursor controlled by the joystick.

4.1.8 Screen overlays:

The alphanumerics on the normal operations overlay should be black characters presented against their own low luminance background. A special control should be provide for adjusting the luminance of the background.

As stated in the results, using either the white overlay or the black overlay can lead to partial obscuration of critical information under certain conditions. Moreover, the operator is unlikely to have or take the time to change the overlay while the system is operating. Thus the overlay should be designed to be visible against all backgrounds. This can be achieved by using black symbols and presenting them against a relatively low luminance grey background that is discriminable from a dark image. In the case of the bar graphs, the use of a 1:1 dashed bar would ensure that bar is visible at all times. To ensure good visibility in different ambient lighting conditions, the luminance of the background of the overlay should be adjustable independently.

4.2 Function allocation

The recommendations outlined above should make the operation of ALBEDOS simpler and faster. However, it would still require a dedicated operator and a high level of control. To reduce workload further would require many of the functions to be automated, at least partially. Often, the decision to automate a function is made based on whether it *can* be automated rather than whether it *should* be automated. This is an incorrect approach. Functions that should be automated are those that can be done as well, or better, by machines as by humans, or that can alleviate the operator from doing secondary tasks. For example, the human operator may be able to adjust the focus better than an automated control. However, if he or she is occupied with other more important tasks, the automated control may be preferable. Moreover, automating this function would allow the operator to concentrate on locating and identifying the target. Based on the evaluations carried out to date, ALBEDOS would be more suitable for SAR operations if some or all of the following modifications were incorporated.

4.2.1 Automated tracking:

Investigate the feasibility of implementing an automatic tracking function in ALBEDOS.

One of the primary difficulties encountered by the participants during the preliminary trials was keeping the camera on a target, especially when they tried to zoom in. This problem was due to the limited experience of the operators, the types of controls used, and the need to adjust the range at the same time. However, it is an inherently difficult task given the narrow field of view of the camera when it is zoomed in and the continuous movement of the aircraft. Thus, one of the most potentially useful functions to automate would be target tracking. With the system tracking the target, the operator could optimize the range, depth, zoom, and possibly the image quality to improve recognition.

4.2.2 Image quality:

An automated mode for controlling the image intensifier offset/gain aperture opening and focus should be included in the next generation of ALBEDOS.

Currently, an automated controller for the image intensifier offset and gain and the aperture size exists. Based on the experience of the developers, there is little requirement for manual control of these functions. Given the many other more critical tasks that the operator has to carry out, it seem unlikely that they would or could outperform the automated systems. For the same reason, an automated focus should be added.

However, operator experience with the manual and automated mode is limited to date. With experience, the operator may outperform the algorithms used by the automated systems especially if an automated tracking system is available. Thus, a thorough evaluation should be carried out to determine the advantage of having an automated controller for these functions. If there is a clear advantage to having an automated mode, it should be made the default for all these functions.

4.2.3 Laser illuminator range:

For SAR operations, the feasibility of slaving the range to the aircraft altimeter or to the laser range finder should be investigated.

Based on the participants' comments, the most suitable function for automating is the range. Implementing this function should reduce the requirement to adjust the range, allowing the operator to concentrate on tracking a target. The participants recommended slaving the range either to the aircraft altimeter or to a laser range finder. However, the advantage to be gained from slaving the range to the altimeter may be limited. The desired range is a function not only of the aircraft altitude but also of the angle of the camera. If the range was set to the aircraft altitude, the operator would still have to adjust it to compensate for the camera angle (unless weather conditions permitted use of a wide depth). These additional adjustments would most likely be required when the aircraft was closing in on a target or circling around to check on a possible target. Under those conditions the operator would be busy adjusting the direction of the camera and possibly the zoom as well. Thus, a laser range finder linked to the direction of the camera would be preferable.

4.2.4 Laser illuminator depth:

A systematic investigation of the relationship between atmospheric visibility and optimum depth should be carried out to see if a simpler depth control can be implemented.

There was not much interest in automating the depth. This may have been due to the fact that the operators rarely adjusted the depth during our trial. However, they also could not conceive of how the depth might be automated.

The depth of the illuminated area is a function of atmospheric visibility. The poorer the visibility, the shorter the depth must be to ensure low scatter. On the other hand, the shorter the depth, the more critical the range and the shorter the time the target will remain in view. Ideally, one would adjust the depth until an optimum signal-to-noise-ratio was achieved. In most cases, the best the operator will be able to do is choose a depth that previous experience has shown is reasonable. To ensure that the operator has that information, data should be collected on the relationship between visibility and depth. The data should include

an estimate of how sensitive the signal-to-noise ratio of the image is to small changes in depth.

If these data were available, the primary depth control could be a multi-position knob in which the different positions correspond to appropriate depths for different levels of visibility. If there was benefit to be gained from subtle adjustment of the depth under certain conditions, a continuous control could be retained as well, for small adjustments.

4.2.5 Automated scanning functions:

An automated scanning mode should be investigated for the laser illuminator range and the camera.

The SAR participants thought that the field of view of ALBEDOS was too small to make it useful when searching for targets whose location is unknown. While this may be true, especially for SAR operations, the search capability should really be evaluated with experienced operators. Part of the problem may be due to the fact that it is difficult for people to search systematically (7). The problem is greater at night or in poor visibility when reference points are not available to guide scanning patterns. There was some evidence of this on the tapes. The operators rarely moved the camera far away from the home position of straight ahead and towards the nose. If they had really been searching for a target, most of the terrain would not have been covered under that condition.

Systematic scanning is even more difficult with a system such as ALBEDOS because the operator must scan the screen while systematically adjusting the camera position and the range of the laser illuminator. These latter problems could be overcome by adding an automatic scanning function to the camera and possibly the laser illuminator range. In an automated scanning mode, the operator would set in the maximum and minimum angle and the camera would sweep back and forth between the two. The scan rate would have to be linked to the aircraft speed to ensure complete coverage. Similarly, the operator would set up a minimum and maximum distance for the laser illuminator and the system would scan the terrain in discrete steps over that range. The step size would have to be a function of the depth. An automated scanning function for the laser illuminator range would probably be most useful with a short depth. With these capabilities, the operator would only have to monitor the scene for bright light sources.

An alternative solution would be to use a different sensor system for the search portion of the task. Since ALBEDOS has a relatively small field of view, a target does not stay within the camera's field of view for very long. Thus, while the contrast between the target and its background may be significantly larger with ALBEDOS than with other sensor systems, the probability of detecting the target may not be that much greater. If another system, with a wider field of view, was used for searching, it could pass the location of possible targets to ALBEDOS for

identification. Of course, this option only makes sense in a multi-sensor aircraft. If ALBEDOS is planned for use in such an environment, it would be useful to investigate the benefits of using an alternate system for the 'panoramic' or search mode as opposed to adding an automatic scanning function.

Investigate the feasibility of implementing an automatic detection function in ALBEDOS.

While the automatic scanning functions would relieve the operator from continuously adjusting the camera and laser illuminator range, the system would still require a dedicated operator. Adding an automatic detection function, would permit the operator to carry out other tasks while the system is in search mode. However, automatic detection algorithms can have high false alarm rates depending on the signal-to-noise ratio. Thus, such a function would probably be most useful over water or uninhabited terrain.

4.3 Limitations of the evaluation

As stated in the introduction, the recommendations for the HMI and function allocation should have been based on formal function and task analysis. A system and task analysis for SAR operations as a whole has been completed (6). If possible, this analysis should be extended to determine the specific role of ALBEDOS in improving SAR operational effectiveness and system characteristics to achieve that goal.

The trials on which the HMI recommendations were based were carried out under a limited range of conditions. To start, the number of participants was limited. Although all of them had a SAR background, none of them were SAR Techs. If the system was employed in SAR operations, SAR Techs would be the primary users. None of the participants had previous experience with using a system such as ALBEDOS for detecting and identifying targets. Ideally, the trial would have included individuals experienced with either ALBEDOS or similar systems as well as inexperience users. Finally, all the trials were carried out a night under relatively clear weather conditions. As further data become available under a wider range of conditions and with a wider range of users, many of the recommendations for the HMI and for allocation of functions may have to be modified.

5. CONCLUSION

During a field trial to test out the technical capabilities of ALBEDOS, DCIEM personnel conducted a limited human factors evaluation of the interface. The evaluation consisted of a static review of the controls and displays based on compliance with MIL-STD-1472D and interviews with military personnel that had used the system to detect and identify targets during the field trial. Based on the information gathered from these sources, it was concluded that the current interface is inconsistent with MIL-STD-1472D, and that it can interfere with the primary function of ALBEDOS, which is to detect and identify targets. Proposals for a new interface and for automating certain functions were developed. It was also recommended that more extensive evaluations of certain functions such as the focus, the vehicle slave mode, and the laser illuminator depth be carried out.

6. RECOMMENDATIONS

1) Prototypes for a new HMI for ALBEDOS should be developed and evaluated. The prototypes should incorporate the design recommendations presented in bold in the discussion section and should take into account the results of the evaluations proposed in recommendations four (4) and five (5), if available.

2) Extend the system and function analysis of the SAR operations to determine how a system like ALBEDOS would be used during SAR operations. Use this information to validate the current recommendations for the HMI.

3) If further development of ALBEDOS is planned, the following additions should be considered:

- linking the laser illuminator range to the output of a laser range finder
- an automated focus control,
- an automated tracking function for the camera,
- an automated scanning function for the laser illuminator,
- an automated scanning mode for the camera, and
- an automated detection function.

4) A further evaluation should be carried out to determine how frequently and when the focus and aperture size are likely to be adjusted.

5) The optimum depth and the sensitivity of the depth adjustment under different visibility conditions should be determined. These data should be used to simplify the depth adjustment of the laser illuminator.

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APPENDIX A: DETAILS OF THE ALBEDOS OPERATOR-MACHINE INTERFACE (OMI)

Camera interface

The operator can control the direction of the camera, its focal length (**zoom**), aperture, focus, and the offset and gain of the image intensifier. Additional controls are available to make the movement of the camera inversely proportional to the zoom or focal length (**zmult**), to set up a home position for the camera (**vehicle slave mode**), and to insert a filter in front of the lens to limit the light entering the camera to those near the frequency of the laser.

The camera can be moved through a vertical range (**tilt**) of +30 to –90, where 0 degrees is parallel to the aircraft, and through a horizontal range (**pan**) of –180 degrees to +180 degrees, where 0 degrees is the nose of the aircraft. When the system is being used for searching, the pan and/or tilt tend to be varied over an extended range. During identification, small continuous adjustments of these controls is necessary to compensate for movement of the aircraft or to center the camera on the object of interest.

The direction of the camera is controlled by a two dimensional pressure joystick located on the right hand side of the console. Pushing the stick to the right moves the camera to the right and vice versa. Similarly, pushing it forward moves the camera up and vice versa.

Information on the current direction the camera is provided on six different displays. Three of the displays provide information on the pan or horizontal direction and an identical set provide information on the tilt or vertical direction. They include position indicator displays on the console to the left (pan) and above (tilt) the joystick, position indicator displays along the bottom (pan) and left side (tilt) of the screen overlay and numeric readouts on the screen overlay to the right of the pan display and below the tilt display.

Two functions are available to assist the operator in controlling the camera direction. The first of these, **zmult**, makes the adjustment of the pan and tilt inversely proportional to the zoom setting. Its purpose is to slow down the rate at which the camera moves when it is zoomed in on an area. The function is enabled by pushing the button labelled "ZMULT" and disabled by pushing the same button. When the function is enabled the term "ZMULT" appears below the numeric value of the zoom. The second function is the **vehicle slave mode**. When enabled, it returns the camera to a home position whenever the operator take his or her hand off the joystick. The operator must first set up the home position by pointing the camera in the desired direction and pushing the button "VEH SLAVE SET". To activate the process the operator pushes down the button "VEH SLAVE". The process can be disengaged by returning the rocker switch to the center position.

The focal length or zoom of the camera allows the operator to zoom in on a small area in order to identify a target or zoom out to get as wide a field of view as possible for searching. It can be adjusted from 16 to 400 mm or from 32 to 800 mm by inserting an optical extender in the optical path. The operator inserts or removes the optical extender by pushing the button labelled "EXT 1X/2X".

As the focal length increases, the field of view changes from wide angle to telephoto. The zoom is adjusted by turning the large force activated knob on the left hand side of the console. Feedback on the current focal length is provided by a bar graph to the right of the knob, a bar graph on the right side of the screen overlay, and a numeric readout above the screen bar graph. The range of the bar graph is either 16-400 mm or 32 to 800 mm depending on whether the optical extender is inserted. As well, there is a separate alphanumeric readout at the top of the screen, to the left of the zoom numeric readout, under the mnemonic "EXT" to indicate whether the optical extender is inserted (2X).

The focus on the camera controls the sharpness of the picture. It can be adjusted between five metres and infinity by turning the small knob on top of the zoom knob. The current distance is shown at the top of the screen under the word "FOCUS".

The size of the aperture opening on the camera affects the amount of light entering the camera. It can be handled automatically by the system or manually by the operator. In manual mode, the size of the aperture opening is increased by pushing or pushing and holding the button labelled "IRIS +" and decreased using the button labelled "IRIS –". To switch between automated and manual mode, the button labelled "AUTO IRIS" is pushed. The current size of the aperture appears below the word "IRIS" on the screen. If the aperture is under automatic control then the word "AUTO" appears below the current aperture size. The relative size of the aperture can also be determined from the position indicator display on the console above the knob for the zoom and focus.

The image intensifier offset and gain can also be run in automatic or manual mode. In manual mode, the offset is increased by pushing or pushing and holding the button "ALC +" and decreased in the same way by the button "ALC –". The image intensifier gain is similarly controlled with the buttons "MPC +" and MPC –". The buttons labelled "ALC AUTO/ MAN" and "MCP AUTO/ MAN" switch control of these functions between the operator and the system. The only feedback provided on the main overlay is whether these functions are in auto or manual mode - "ALC1" and "MPC1" for automatic and "ALC2" and "MPC2" for manual.

The last function associated with the operation of the camera is inserting a narrow band filter in front of the lens. The filter is centered on the frequency of the laser. It can be switched in or out by pressing the button "FILTER". The current

status of the filter is shown on the main overlay by the words "ON" or "OFF" under the mnemonic "FIL".

Laser illuminator interface

The operator can arm and activate the laser and, in an emergency, block the laser beam. While the laser is operational, the operator can control the distance from the camera at which the laser begins illuminating the scene, the distance over which the scene is illuminated, and the width of the illuminated area.

The laser is armed by pushing the button labelled "LASER ON" while simultaneously turning the key in the center top of the console. Once the laser is armed, the word "ARMED" replaces the word "SAFE" on the bottom center of the screen and the "LASER ON" button is illuminated. If the "LASER ON" button is pushed again, the laser is disabled. To activate the laser, the operator must push the button labelled "ACTIVE/PASSIVE". Pushing it again turns off the laser beam, but leaves the laser armed. When the laser beam is in active mode the mnemonic "ACT" appears on the bottom of the screen. When passive mode is selected the mnemonic "PAS" appears instead. As well, there is an emergency button, near the center bottom of the console, which, when pushed, pivots the dome window away from the line of sight of the camera and the laser, effectively blocking the laser beam. At the same time, the message "BEAM ATTENUATED" appears in the middle of the screen.

The distance from the camera that a scene is illuminated is controlled by pushing or pushing and holding the buttons "RANGE +" or "RANGE –". As well, the focus knob can be turned into a coarse range control by pushing the button "FOCUS SLAVE". When this occurs the word "SLAVE" appears on the screen under the value for the focus. The buttons are still used for fine adjustments in this mode. The current distance in metres is shown at the top of the screen under the mnemonic "RNG". The length of time the camera is gated open or the distance over which the scene is illuminated is adjusted by pushing or pushing and holding either "GATE +" or "GATE –". The use of the term gate comes from the fact that the depth is a function of the length of time the aperture is gated open. The current distance is shown at the top of the screen under the mnemonic "DPTH". Both of the above distances can be varied continuously. The width of the illuminated area assumes only two discrete sizes — narrow (2 degrees) and wide (10 degrees). The width is changed by pushing the button "ILLUM FOV". The current width is shown at the top of the screen under the mnemonic "FOV" by W for wide and N for narrow.

Gyro stabilizer interface

The gyrostabilizer system keeps the camera horizontal at all times. It is enabled by pushing the button "GYRO ON". When the system is first turned on, the message "GYRO STOPPED" appears in the middle of the screen. While the system is coming up, this message changes to "STARTING XX" where XX is the gyro start

time counter. Once the system has reached operating speed this message is removed. If the aircraft goes into a long slow turn, the gyro's interpretation of horizontal may be distorted. After the aircraft comes out of the turn, it may take several minutes for the gyro to bring the camera back to true horizontal. This process can be speeded up by pushing and holding the button labelled "RAPID REACT". While the button is being held, the status overlay appears on the screen.

Screen overlays

The operator can call up three different screen overlays. However, the normal operation overlay (Figure 1) is intended to provide all the information required while the operator is locating and identifying targets. The other two, the status and mode overlays, are used only if the operator wants to check the status of system parameters or to modify the characteristic of the laser illuminator. The design and content of these latter two overlays were not part of the evaluation. All references below to the screen overlay refer to the normal operation overlay.

The screen overlays can be displayed in six different formats — white full on, white partial on, white off, black full on, black partial on, and black off. In the partial on modes, the information at the top of the screen is not displayed. These modes can be accessed in turn by repeatedly pushing the button labelled "OVERLAY SET". The other overlays are accessed by pushing the button "STATUS" for the status screen and "MODE" for the set-up overlay screen. Values on the latter screen can be changed by using the zoom control to select the parameter and the "IRIS +" "IRIS –" switch to adjust the parameter.

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ALBEDOS (Airborne Laser Based Enhanced Detection and Observation System) is an active imaging device designed to enhance surveillance capability at night and under degraded weather conditions. It is currently being developed for use in search and rescue (SAR) operations. DCIEM was requested to carry out a human factors evaluation of the ALBEDOS human-machine interface (HMI) as part of a technical evaluation of the system. The human factors evaluation included a desktop analysis of the HMI for compliance with MIL-STD-1472D and structured interviews with potential users of the system. The users participated in the technical trials and carried out several scenarios that involved detecting and identifying targets at night.

The results of the desktop evaluation indicated that the current ALBEDOS interface does not meet MIL-STD-1472D. The participants' comments supported this finding. They thought that the system could be useful for identifying targets at night and under degraded weather conditions. However, due to the current physical and manpower constraints of the SAR environment, the interface should be simplified considerably and many of the functions should be automated.

Alternative concepts for the ALBEDOS HMI are discussed. It is recommended that these concepts be prototyped and evaluated by potential users. In some cases, functions were not tested sufficiently because of time constraints and the inexperience of the participants. Thus, clear recommendations could not be made. In those cases, suggestions for further evaluations are presented. In addition, feasibility studies on automating certain functions are proposed.

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